# APPARATUSES AND METHODS FOR PREVENTING FOREIGN OBJECT DAMAGE TO AIRCRAFT ENGINES

## CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to U.S. Provisional Application 60/420,748, filed October 22, 2002 and incorporated herein in its entirety by reference.

## TECHNICAL FIELD

[0002] The following disclosure relates generally to apparatuses and methods for preventing foreign object damage (FOD) to aircraft engines and, more particularly, to main landing gear door assemblies and other blocking structures for preventing FOD to aircraft engines.

## BACKGROUND

[0003] Foreign object damage (FOD) to an aircraft engine can cause an unexpected engine shut-down or an unscheduled engine replacement. Such FOD can be caused by various types of debris, including runway debris (e.g., water, gravel, nuts and bolts, etc.) and aircraft debris (e.g., tire pieces, accumulated ice, landing gear parts, etc.). These types of debris can be thrown or otherwise propelled into the engine inlet by a landing gear wheel during take-off or landing, especially if the wheel is positioned forward of the engine air inlet. Existing structures for preventing foreign materials from being ingested into the engine inlet may be heavy and/or may not block all such materials. For example, some existing devices may block water but not solid objects, and others may block only certain material trajectories.

## SUMMARY

[0004] The present invention is directed generally toward aircraft devices for intercepting foreign objects to prevent foreign object damage. An aircraft in accordance with one aspect of the invention includes a fuselage portion, a wing portion coupled to the fuselage portion, and an engine nacelle having an air inlet and depending from at least one of the fuselage portion and the wing portion. A landing gear can also depend from at least one of the wing portion and the fuselage portion. A deployable blocker can be coupled to at least one of the wing portion and the fuselage portion and can be movable between a stowed position and a deployed position, with at least a portion of the blocker being located between the landing gear and the air inlet when in the deployed position to prevent at least a solid object propelled by the landing gear from entering the air inlet.

[0005] In a further aspect of the invention, the landing gear is movable between an extended position and a retracted position, and the blocker can cover at least a portion of the landing gear when the landing gear is in the retracted position and the blocker is in the stowed position. The landing gear can include at least one tire and the blocker can intersect a straight line extending between the at least one tire and the air inlet. In another embodiment, the blocker can prevent at least a solid object propelled by the landing gear from striking a lower surface of the wing portion and then entering the inlet. In still another embodiment, the blocker can include a blocker device positioned between an upper surface of a landing gear tire and at least one of the wing portion, the fuselage portion, and the engine nacelle to intercept at least a solid object propelled by the landing gear. The blocker device can be supported by the landing gear from a position below the blocker device.

[0006] A method in accordance with another aspect of the invention includes extending the landing gear of an aircraft, engaging the landing gear with the ground, and moving the aircraft along the ground on the landing gear. The method can further include preventing at least a solid object propelled by the landing gear from entering an engine inlet of the aircraft by moving a deployable blocker coupled to at least one of the wing portion and the fuselage portion of the

aircraft from a stowed position to a deployed position to place at least a portion of the blocker between the landing gear and the inlet. In a further aspect of this embodiment, the method can include preventing a tire fragment from entering the inlet. In other particular embodiments, the method can include preventing at least a solid object from striking at least one of the wing portion and the fuselage portion and then bouncing into the inlet, and/or sticking to at least one of the wing portion and the fuselage portion and falling into the inlet.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Figure 1 is a front elevation view of a portion of an aircraft having a blocker assembly configured in accordance with an embodiment of the invention.

[0008] Figure 2 is a side elevation view of a portion of the aircraft of Figure 1 illustrating aspects of the blocker assembly configured in accordance with an embodiment of the invention.

[0009] Figure 3A is a front elevation view, and Figure 3B is a side elevation view, of a portion of an aircraft having a blocker assembly configured in accordance with another embodiment of the invention.

[0010] Figure 4 is a bottom plan view of a portion of the aircraft shown in Figure 3A, configured in accordance with an embodiment of the invention and illustrating possible ranges of debris trajectories.

[0011] Figure 5A is a front elevation view, and Figure 5B is a side isometric view, of a portion of an aircraft having a blocker assembly coupled to a landing gear and configured in accordance with an embodiment of the invention.

[0012] Figure 6 is an enlarged rear elevation view of a lower portion of a landing gear illustrating aspects of the blocker assembly of Figures 5A-5B configured in accordance with an embodiment of the invention.

[0013] Figure 7 is an enlarged isometric view of the lower portion of the landing gear of Figure 6 illustrating aspects of the blocker assembly configured in accordance with an embodiment of the invention.

[0014] Figure 8 is a top view of a wheel truck illustrating further aspects of the blocker assembly of Figures 5A-7 configured in accordance with yet another embodiment of the invention.

## DETAILED DESCRIPTION

[0015] The following disclosure describes blocker devices, including landing gear door assemblies and related structures for preventing FOD to aircraft engines. Certain specific details are set forth in the following description and the Figures to provide a thorough understanding of various embodiments of the invention. Certain well-known details often associated with aircraft and aircraft landing gears are not set forth in the following disclosure, however, to avoid unnecessarily obscuring the various embodiments of the invention. Further, those of ordinary skill in the relevant art will understand that they can practice other embodiments of the invention without several of the details described below.

[0016] Figure 1 is a front elevation view of a portion of an aircraft 100 having a blocker assembly 102 configured in accordance with an embodiment of the invention and positioned to intercept at least solid foreign objects and prevent them from striking other parts of the aircraft 100. Accordingly, the blocker assembly 102 can also intercept non-solid objects (e.g., water droplets or spray) and prevent them from striking other parts of the aircraft 100. In one aspect of this embodiment, the aircraft 100 is an aft wing aircraft having a wing or wing portion 120 extending outwardly from an aft portion of a fuselage or fuselage portion 110. The aircraft 100 can further include a smaller wing or canard (not shown) extending outwardly from the fuselage 110 forward of the wing 120. In other embodiments, the aircraft 100 can have other wing configurations. For example, in another embodiment, the aircraft 100 can have a mid-wing configuration or a blended wing-body configuration.

[0017] In another aspect of this embodiment, the aircraft 100 has landing gear 101, which includes a nose gear 103 and main landing gear 104 aft of the nose gear 103. An engine nacelle 112 is positioned above the landing gear 101 and can house a turbofan engine. Certain aspects of the invention, discussed below in the

context of the main landing gear 104, are also applicable to other portions of the landing gear 101, for example, the nose gear 103. The main landing gear 104 can be pivotally attached to the wing 120 at a trunnion 108 and can include a wheel truck 106. The main landing gear 104 can be pivotable about the trunnion 108 to move the wheel truck 106 between a static deployed position for supporting the aircraft 100 on the ground (as shown in Figure 1), and a static retracted position (not shown) in which the main landing gear 104 is stowed for flight in a wheel well 130 within the wing 120. For example, in the illustrated embodiment the main landing gear 104 is forwardly retractable into the wheel well 130 about the trunnion 108 between the static deployed position and the static retracted position. In other embodiments, the main landing gear 104 can retract in other directions. For example, in another embodiment, the main landing gear 104 can retract rearwardly into the wheel well 130. In a further embodiment, the main landing gear 104 can retract inwardly, at least partially into the fuselage 110.

[0018] In a further aspect of this embodiment, the engine nacelle 112 is fixedly attached at least proximate to a lower wing surface 122 and includes an engine air inlet 114. In the illustrated embodiment, the engine air inlet 114 is positioned at least generally aft of the wheel truck 106 when the wheel truck 106 is in the static deployed position. In another aspect of this embodiment, the blocker assembly 102 includes a solid and generally rigid panel 105 that is hingedly attached to the wing 120 and is movable between an open or deployed position (as shown in Figure 1), and a closed or retracted position. In the closed position, the blocker assembly 102 can close off the wheel well 130 and can accordingly function as both a landing gear door and blocker for foreign objects. In the deployed position, the blocker assembly 102 extends downwardly to block at least some (and in at least one embodiment, all) direct lines-of-sight between the wheel truck 106 and the engine air inlet 114. Such lines-of-sight can be defined by the region extending between lines 130a and 130b. Accordingly, the blocker assembly 102 of the illustrated embodiment prevents debris generated, kicked-up or otherwise propelled by the wheel truck 106 from travelling on a direct trajectory to the engine air inlet 114 and being ingested by the engine nacelle 112.

[0019] Figure 2 is a side elevation view of a portion of the aircraft 100 of Figure 1 illustrating the blocker assembly 102 configured in accordance with an embodiment of the invention. In one aspect of this embodiment, the blocker assembly 102 includes a gear door portion 201 and a FOD portion 203. The FOD portion 203 can extend close enough to the ground and far enough aft in the deployed position to block line-of-sight trajectories from the wheel truck 106 to the engine air inlet 114. The gear door portion 201 can be configured to close off at least a portion of the wheel well 130 when the main landing gear 104 is retracted.

[0020] In a further aspect of this embodiment, the gear door portion 201 and the FOD door portion 203 can be longitudinally aligned with each other and at least partially integrated as a single hinged panel that can be hydraulically or mechanically deployed as the wheel truck 106 moves into the static deployed position, and mechanically locked in a closed or retracted position when the wheel truck 106 moves into the static retracted position. When the blocker assembly 102 is in the retracted position, the gear door portion 201 can at least partially cover the wheel well 130, while at least part of the FOD portion 203 can be positioned at least approximately flush against the lower wing surface 122 adjacent to the wheel well 130. One advantage of this configuration is that both functions (i.e., wheel well coverage and FOD prevention) can be accomplished without having to construct and integrate two separate mechanical systems into the wing 120. In other embodiments, each of the gear door portion 201 and the FOD portion 203 can cover more or less of the wheel well 130. For example, if the wheel well 130 is extended further aft in the wing 120 than is shown in Figure 2, then the entire FOD portion 203 can be configured to cover at least a portion of the wheel well 130. In yet other embodiments, the gear door portion 201 and the FOD portion 203 can be separate from each other and independently movable relative to each other.

[0021] In a further aspect of this embodiment, the profiles of the gear door portion 201 and the FOD portion 203 are configured to minimize surface area while still providing adequate FOD protection. The profile of the gear door portion 201 can include a swept or highly-swept leading edge 204 to reduce or eliminate vortex

shedding from the blocker assembly 102 into the engine air inlet 114. In other embodiments, the gear door portion 201 and the FOD portion 203 can have other profiles without departing from the spirit or scope of the present invention. For example, in another embodiment, the profile of the gear door portion 201 can be at least approximately rectangular without the swept leading edge 204.

[0022] Figure 3A is a front elevation view, and Figure 3B is a side elevation view, of a portion of an aircraft 300 having a blocker assembly 302 configured in accordance with another embodiment of the invention. Referring to Figures 3A and 3B together, in one aspect of this embodiment, the aircraft 300 has a mid-wing configuration with a wing 320 extending outwardly from a mid portion of a fuselage 310. The aircraft 300 can have a landing gear 301 that includes a main landing gear 304. An engine nacelle 312 is positioned above the landing gear 301. The main landing gear 304 can include a wheel truck 306 and can be at least approximately similar in structure and function to the main landing gear 104 described above with reference to Figure 1. The engine nacelle 312 can be fixedly attached to a wing lower surface 322 and can include an engine air inlet 314. In contrast to the engine air inlet 114 of Figure 1, the engine air inlet 314 is positioned forward of the wheel truck 306 when the wheel truck 306 is in a static deployed position as shown in Figure 3A. Accordingly, debris cannot travel on a direct line-of-sight trajectory from the wheel truck 306 to the engine air inlet 314. As a result, the blocker assembly 302 does not need to extend as far downwardly as the blocker assembly 102 of Figure 1 to prevent such debris from entering the engine nacelle 312.

[0023] Figure 4 is a bottom plan view of the portion of the aircraft 300 shown in Figures 3A and 3B, illustrating ranges of debris trajectories. In one aspect of this embodiment, the wing 320 includes a leading edge 324 positioned forward of the engine air inlet 314. Debris generated or kicked up by the wheel truck 306 can be directed forwardly and upwardly from the wheel truck 306 and can strike the lower wing surface 322 in a first zone 326 (e.g., a bounce zone) or a second zone 328 (e.g., a stick zone). The first (bounce) zone 326 extends laterally inboard from the engine air inlet 314. Debris from the wheel truck 306 striking the first (bounce)

zone 326 can bounce or reflect back relative to the aircraft 300 at an angle into the engine air inlet 314, as indicated by bounding trajectories 340 (shown in phantom lines). The second (stick) zone 328 is laterally aligned with the engine air inlet 314, as indicated by dashed lines 341. Debris from the wheel truck 306 striking the second (stick) zone 328 may temporarily stick to the lower wing surface 322 and subsequently detach and travel directly aft relative to the aircraft 300, parallel to the line of flight and into the engine air inlet 314. Accordingly, in the illustrated embodiment, the blocker assembly 302 is expected to prevent all debris from the wheel truck 306 from striking the the second zone 328 and travelling back into the engine air inlet 314. The blocker assembly 302 may not block all debris from the wheel truck 306 from striking the first zone 326.

[0024] In another embodiment, the blocker assembly 302 can include an extension 460 (shown in dashed lines in Figure 4) extending forward toward the wing leading edge 324. The extension 460 can, in one aspect of this embodiment, be fixed relative to the lower wing surface 322. In other embodiments, the extension 460 can be at least partially integrated with the rest of the blocker assembly 302 to hingedly open and close relative to the lower wing surface 322. In any of these embodiments, the extension 460 can completely or at least more completely block debris propelled by the wheel truck 306 from striking the first zone 326.

[0025] Figure 5A is a front elevation view, and Figure 5B is a side isometric view, of a portion of an aircraft 500 having a blocker assembly 550 (for example, a "FOD bonnet") configured in accordance with an embodiment of the invention. Referring to Figures 5A and 5B together, in one aspect of this embodiment, the aircraft 500 includes a main landing gear 504 having a wheel truck 506. The wheel truck 506 includes a chassis 560 that carries wheels 507 with tires 508. The main landing gear 504 can be pivotally attached to a wing 520 with a strut 505 and can be inwardly retractable for stowage at least partially within a fuselage 510 during flight. In other embodiments, the main landing gear 504 can retract in other directions for stowage during flight. For example, in other embodiments, the main landing gear 504 can retract either forwardly or rearwardly for stowage in the wing 520. In another aspect of this embodiment, the aircraft 500 includes an engine

nacelle 512 having an engine air inlet 514 positioned forward of the wheel truck 506 in a manner generally similar to that of the engine air inlet 314 described above with reference to Figures 3A and 3B. In a further aspect of this embodiment, the blocker assembly 550 can prevent debris directed forward from the wheel truck 506 from striking a lower wing surface 522 and then traveling back relative to the aircraft 500 and into the engine nacelle 512 via the engine air inlet 514.

[0026] Figure 6 is an enlarged rear elevation view of a lower portion of the main landing gear 504 illustrating aspects of the blocker assembly 550 of Figures 5A-5B configured in accordance with an embodiment of the invention. In one aspect of this embodiment, the blocker assembly 550 includes a support structure 552 and a deflector panel 554. The deflector panel 554 is positioned above the upper surfaces of the tires 508, and can be at least approximately horizontal with respect to the ground, or inclined upwardly or downwardly as it extends over at least a portion of the wheel truck 506. The deflector panel 554 can extend laterally from the strut 505, and can extend further on one side of the strut 505 than the other, based on the relative position of the engine air inlet 514 (not shown). The deflector panel 554 can further include a cutout 556 to accommodate the strut 505.

[0027] In another aspect of this embodiment, the support structure 552 attaches the deflector panel 554 to the chassis 560 of the wheel truck 506. For example, the support structure 552 can be attached to axles 509 on which the wheels 507 are mounted. In other embodiments, the support structure 552 can be attached to other portions of the landing gear 504 or other structural members without departing from the spirit or scope of the present invention. For example, in another embodiment, the blocker assembly 550 can be mounted to at least a portion of the strut 505 instead of the wheel truck chassis 560. In any of these embodiments, the support structure 552 can support the deflector panel 554 from below. One feature of this arrangement is that debris from the wheel truck 506 impacting the deflector panel 554 can impart tension loads on the support structure 552. Tension loads can generally be carried by the structural members of the support structure 552 more efficiently than compression loads. Accordingly,

the support structure 552 of the illustrated embodiment can be made lighter than a support structure that carries loads imparted to the deflector panel 554 in compression (e.g., a support structure that carries the deflector panel 554 from above). Another feature of this arrangement is that the deflector panel 554 follows the motion of the tires 508 because the deflector panel 554 is supported by the truck 506. An advantage of this feature is that the deflector panel 554 can more consistently block trajectories originating at the tires 508, even as the tires 508 bounce on the runway, or assume a "toes up" or "toes down" attitude just prior to touchdown or after takeoff.

[0028] Figure 7 is an enlarged isometric view of a lower portion of the landing gear 504 illustrating further aspects of the blocker assembly 550 shown in Figures 5A and 5B.

[0029] Figure 8 is a top view of the wheel truck 506 illustrating further aspects of the blocker assembly 550 shown in Figures 5A and 5B.

[0030] From the foregoing, it will be appreciated that specific embodiments of the invention have been described herein for purposes of illustration, but that various modifications may be made without deviating from the spirit and scope of the invention. Accordingly, the invention is not limited except as by the appended claims.